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The heavy metal threat to drinking water supply

GEA OLIVERI CONTI, CHIARA COPAT, LETIZIA FERLITO, ALFINA GRASSO, GIOVANNI ARENA, MARIA FIORE, CATERINA LEDDA and MARGHERITA FERRANTE discuss sources and issues surrounding heavy metal contamination of drinking water sources and outline further research required in order to properly understand its impacts.

Heavy metals appear naturally in drinking water sources as well as resulting from human activities and although some are essential for health, excessive levels can have an adverse impact (see box).

Problems in drinking water sources and subsequently in drinking water supplies can include high iron and manganese concentrations; common in Central and Eastern European countries where it often occurs naturally in groundwater. Other heavy metals include lead, arsenic and mercury. For many heavy metals, knowledge is incomplete with regards to the impact of high levels on human health when ingested through drinking water. This is particularly true for selenium, boron and vanadium, which appear naturally in volcanic regions, and depleted uranium from ammunition in areas of conflict.

Selenium

Selenium is found naturally in drinking water sources, leaching from volcanic rock and soils, and it can also be present due to various human activities such as coal combustion, glass production, electronics manufacturing and oil refining.

Studies investigating the relationship between selenium, cancer risk and cardiovascular health have resulted in very mixed and intriguing findings. Vinceti (2010) carried out studies in Italy in an area where tap water had a selenium content of around 8μg/l and the results suggested that there was an increased risk of melanoma and lymphoid malignancies, as well as motor neurone disease.

However, other studies from the US have found no link between communities with high doses of selenium in their drinking water and an increased risk of associated illnesses. There has also been significant interest in selenium's potential antioxidant and anti-carcinogen activity. However, its alleged anticancer properties have not been convincingly proven.

This diversity in results means we need a better knowledge of the toxicological effects of this metal in order to improve risk management related to its presence in drinking water.

Boron

The 2000 EU Water Framework Directive requires EU member states to comply with a number of water quality and health standards; the revisions to the 1998 Drinking Water Directive have added several new chemical parameters besides setting a threshold for boron in drinking water (1mg/l). The directive mostly involves the Mediterranean member states (Cyprus, Greece, Italy, and Spain), where some groundwater bodies contain exceptionally high boron concentrations. EU legislation has thus taken a cautious stance given the inconclusive scientific evidence on the health effects of this potential pollutant.

The new boron standard has created important problems for some EU member states faced with the need to devise timely and economically viable management solutions for boron management in drinking water. Experiments and studies have demonstrated that boron in drinking water is not harmful up to a concentration of 2.4mg/l, the WHO guideline value. This is higher than the EU limit (Drinking Water Directive). Adoption of the WHO standard has therefore made several water resources available that had until recently been excluded. This is especially true of volcanic areas such as southern Italy, where the Catania research group recently described the effects of boron in a study carried out in Eastern Sicily (Fiore et al., 2013) (see box).

Eruption of Mount Etna April 2012. Drinking water in volcanic regions can contain elevated levels of heavy metals such as boron, vanadium and selenium. Credit: RZ Design / Shutterstock.com.

Vanadium

A further problem in volcanic areas is the presence of vanadium in drinking water. Vanadium dissolves in natural waters as V(IV) and V(V). Their coexistence in aqueous solution depends on water pH, the concentration and reduction-oxidation potential of the metal, and the ionic strength of the system. Trace amounts are essential for normal cell growth; vanadium enhances glucose transport and metabolism in different tissues and cell types, promotes glycogen synthesis and lipogenesis, and inhibits lipolysis and gluconeogenesis. On the other hand, high V(V) blood concentrations may cause adverse effects such as nephrotoxicity and reproductive and developmental toxicity. Despite extensive investigation of the toxicity of V(V), little is known of the effects of high-level exposure on human health, nor have thresholds been set by national or international bodies or institutions such as the European Food Safety Authority (EFSA) or WHO.

Depleted uranium

In the early 1970s the US began to use depleted uranium to make anti-tank ammunition. Environmental

Metals and health

Trace amounts of metals are common in water and are generally not harmful to humans. Some metals (e.g. Ca, Mg, K, and Na) are actually essential to maintain health whereas others (e.g. Co, Cu, Fe, Mn, Mo, Se, and Zn) are required in extremely low amounts as catalysts and co-factors for enzyme activities. However, oral exposure to excess amounts of any one of the metals that are nutritionally essential may induce acute or chronic toxicity and in some cases even promote cancer.

Drinking water thus may also be a source of chronic exposure to toxic heavy metals and metalloids that are not essential for the body, like arsenic, cadmium, hexavalent chromium, lead, mercury and nickel. Chronic exposure to heavy metals in drinking water includes a variety of adverse health effects; nearly all organ systems are involved, especially the central nervous, cardiovascular, hematopoietic, gastrointestinal and renal system. Arsenic, lead, mercury, cadmium, hexavalent chromium and nickel also exert carcinogenic effects.

and toxicological issues related to environmental exposure to depleted uranium were raised by specialists following the wide-scale use of this ammunition by the US Army.

Despite the widely-believed toxicity of depleted uranium ingested through drinking water in areas recently affected by war, this has actually yet to be proved. Direct skin contact is unlikely to result in radiation-induced erythema (superficial inflammation) or other short-term effects. Follow-up studies of veterans with fragments embedded in tissue have shown detectable urine levels of depleted uranium that were not ostensibly associated with important health consequences.

Higher tumour rates, reported both in populations and among veterans, raised the suspicion that depleted uranium could be the shared risk factor. However, genomics research, like the Italian SIGNUM Project, which assessed the genotoxic impact of depleted uranium in Italian peacekeeping troops deployed in Iraq in 2003-2006, has begun to show that the cause should be sought among other stressors. Gulf War veterans for example were exposed to a unique mix of hazards not previously experienced during wartime. These included pyridostigmine bromide pills given to protect troops from the effects of nerve agents, depleted uranium munitions, and anthrax and botulism vaccines.

The few US studies undertaken on test sites where there were large amounts of depleted uranium did not reveal any contamination of local ground, however it cannot be excluded that in the long-term depleted uranium might contaminate local groundwaters in Kosovo (UNEP, 2001) or in other conflict areas, so persistent groundwater monitoring is required to assess the risk to communities exposed through ingestion of local tap water.

Conclusion

Research is in progress to determine the concentration limits for metals in drinking water. Some important issues, like the identification and assessment of the risks related to chronic, low-level environmental exposure to metals and more complex compounds, are still outstanding. These should be major research goals, while efficient risk communication should be adopted at all levels. ●

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Impact of boron in Eastern Sicily

It is known that the majority of boron dissolved in the groundwater of the Etna volcanic area in Eastern Sicily is linked to its geomorphological characteristics, so the resident population has been exposed to boron for decades. In 2011, the European Parliament queried the limit of boron in water intended for human consumption, regarding an increase of the limit from 1mg/l to 2.4mg/l to match that set by WHO.

The results obtained by Fiore et al (2013) supported this new limit. Some wells and springs in Eastern Sicily can have an average content of boron of between 1.09 and 2.33mg/l. The study evaluated the correlation between the content of boron in the blood of 299 healthy male individuals and levels in drinking water, along with the birth rate, mortality rate and sex ratio. The birth rate in areas of high concentrations of boron was higher than that in areas with a low boron concentration and the mortality rate in areas with a high boron concentration was lower than that in areas with a low boron concentration.

Water scarcity and decreasing quality

The poor chemical and microbiological quality of water does not always discourage its use. A study by our group (Copat et al., 2013) in Guinea Bissau, West Africa (the fourth poorest country in the world) provides information on the potential impact of human consumption and associated conditions. Drinking water from ten sites in Oio and Cacheu, two regions in the north of the country, was collected in February 2013. The samples contained various metals, some of which (Fe, Pb, Mn and Al) were found at concentrations exceeding WHO thresholds, highlighting the role of maintenance procedures and system characteristics, alongside the potential toxicity to local populations.